

Minority and Women Training in Advanced Photonics

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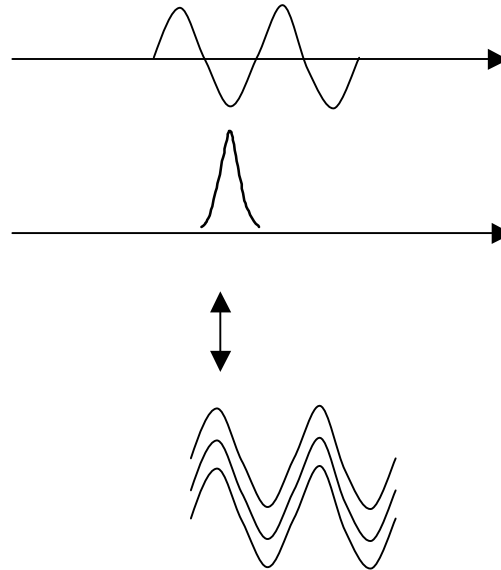
**Institute for Ultrafast Spectroscopy and Lasers
City College of New York
Physics Department**

Robert R. Alfano
Distinguished Professor and Director

Salient Properties and Processes of Light

Salient properties:

- **Wavelength (color)**
- **Time**
- **Polarization**
- **Coherence**



Processes

- **emitted – fluorescence spectroscopy**
- **absorbed – excitation spectroscopy**
- **scattered – Raman and elastic**

Key Equations and Basic Units of Light

$$E = h\nu$$

$$c = \lambda\nu$$

$$E = 1.24/\lambda(\mu\text{m}) \text{ eV}$$

Wavelength: μm – micrometer = 10^{-6} m

nm – nanometer = 10^{-9} m

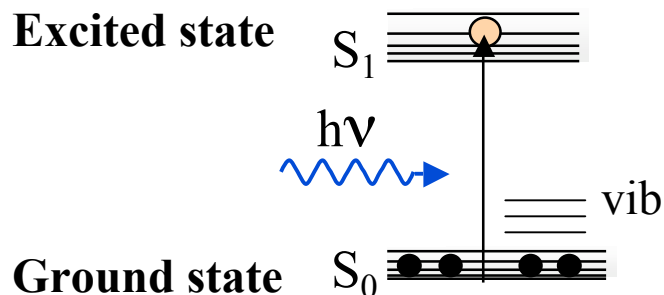
cm^{-1} – wavenumber ($\nu = 1/\lambda$)

$\lambda = 500 \text{ nm} = 0.5 \mu\text{m}$ – green light = $20,000 \text{ cm}^{-1} = 2.48 \text{ eV}$

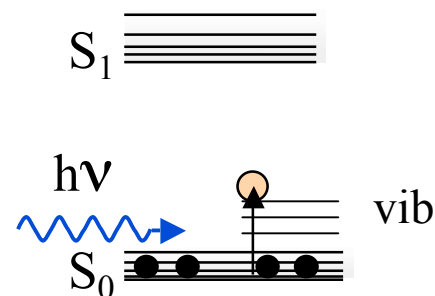
Time: $\text{ps} = 10^{-12} \text{ s}$

$\text{fs} = 10^{-15} \text{ s}$

$\text{as} = 10^{-18} \text{ s}$



UV/visible – excites electronic states



NIR – excites vibrational states

Photonics

Consist of:

- Linear optics
- Nonlinear Optics: SHG, 4WM, SC
- Optical Fibers
- Lasers
- Photodetectors
- Imaging
- Modulation

Applications:

- Communication
- Medical Imaging and Diagnosis
- Biophysics
- Computation
- Photodetectors
- FSO

IUSL Offers Hands-on Training for Students in Cutting Edge Areas of Photonics

Examples:

- **Optical Imaging Through Highly Scattering Media**
- **Cr based tunable NIR lasers from 1100 nm to 1600 nm**
- **Ultrafast lasers and spectroscopy**
- **Time resolved spectroscopy**
- **Photo detectors**
- **Quantum dots and wells**
- **NLO – SC generation (ultrawhite light source)**

NASA prior support of the IUSL Photonics Research

1994 – todate (2009)

PI: Robert Alfano

**NASA IRA – Tunable Solid-State Lasers
and Optical Imaging** **1994 – 2002**

**NASA FAR - Picosecond Gated Optical
Imaging of Dense Fuel Sprays** **1997 - 2001**

**NASA University Research Center (URC)
for Optical Sensing and Imaging
for Earth and Environment
(Director R. Alfano 2003-2007)** **2003 - 2008**

**NASA grant - Biophotonic plant (moss) stress
Detection (Pilot study of gravity
effects on living things)** **2009 (current)**

“15 YEARS”

Goals of Program for Students

Graduate (G), Undergraduate (UG) , High School (HS)

- Summer program for selected HS and UG
- Learn basic principles of optics
- Learn basic principles of spectroscopy, lasers
(using a training guide)
- Join a research team in a focus area
- Learns skills set in the area
- Perform experiments to produce an article with the team

Size of the Program

Before 2006: HS – 17, UG – 10, G- 10;

Current: HS – 5, UG – 3, G – 3.

Metrics

- Monthly reports during training
- Monthly reports, presentations
- Research write up
- Publications

Students at IUSL

Ph.D. graduates	– 50	(5 minorities, 7 – women)
Current Ph.D. students	– 4	
Graduate	- 25	(2003-2009)
Undergraduate	- 96	(2003-2009)
High School	- 80	(2003-2009)

Publications

2004	2005	2006	2007	2008	2009
13	15	16	14	8	5

Research Team

Each research team consists of:

Leader (faculty or postdoctoral researcher)

1 - 2 graduate students

1 - 2 undergraduate students

1 high school student

Aim of team

Perform research using cutting edge instrumentation
to produce publications

Typical Examples of Research

Growth of Tunable Laser Crystals Based on Cr^{4+} , Cr^{3+} and Other Lasing Ions

Tunable solid-state lasers allow the user to customize the source to the application. An integral part of this light source is the laser medium. Laser crystals, based on tetravalent chromium (Cr^{4+}) ion operate in the technologically important near infrared (1-2 μm) spectral region.

Applications:

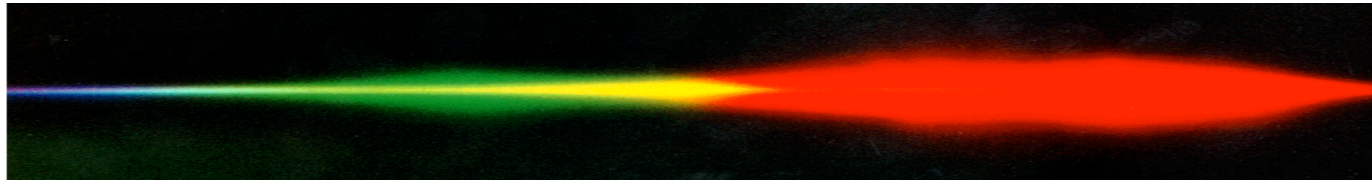
The 1-2 μm spectral range, includes wavelengths at 1.3 and 1.5 μm , both important for optical communications, and the eye-safe wavelength range beyond 1.45 μm . Possible uses include optical communications, eye-safe ranging and remote sensing, and biomedical and scientific applications.

LIGO – 1100 nm to 1600 nm



Supercontinuum (SC)

Ultimate White Light



Spans: 400 nm to 1400 nm

Energy: 1mJ; pulse < 1 ps

Spectral energy brightness: 1 mJ/1000nm = $\mu\text{J}/\text{nm}$

Focus to 100 μm gives 10 mJ/nmcm²

Spectral power brightness:

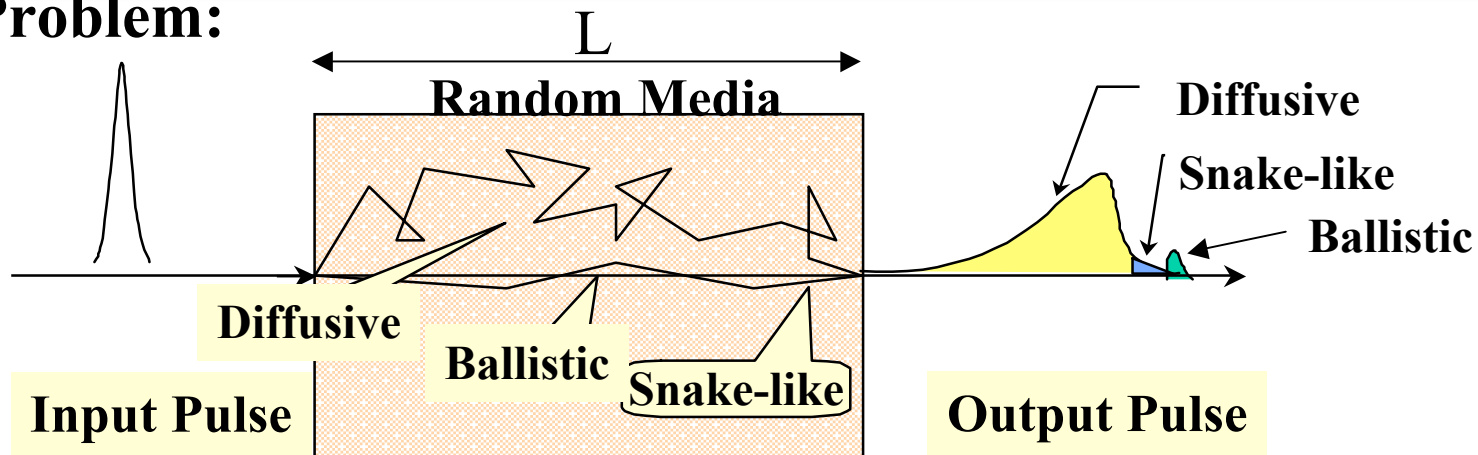
10mJ/nmcm²ps = $10 \times 10^9 \text{ W/ nmcm}^2$ = 10 GW/nmcm²

Applications:

- accurate clocks \longrightarrow Nobel prize (2006)
- chemistry/biology \longrightarrow Nobel prize (1999)
- communication
- NLO
- nm microscopy

Pulse propagation through scattering walls

Problem:



$$\overline{Z}_D \sim L^2/(2l_t) \text{ (diffusive)}$$

$$l_t = 1 \text{ cm}, L = 1000 \text{ cm}$$

$$\overline{Z}_B = L \text{ (ballistic)}$$

$$\overline{Z}_D = (10^3)^2/2 = 5 \times 10^5 \text{ cm}$$

$$\overline{Z}_B = 10^3 \text{ cm}$$

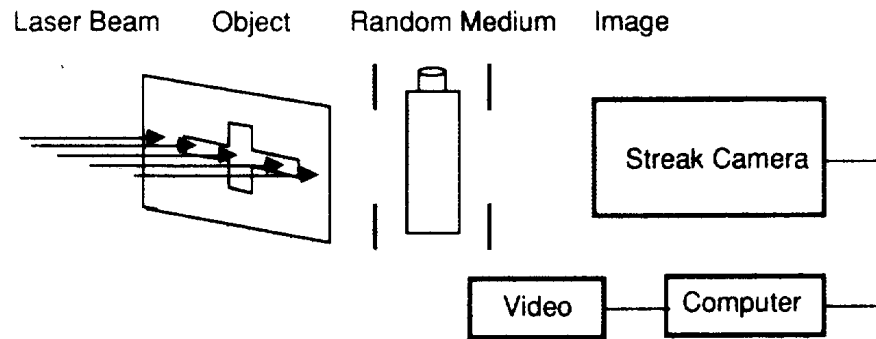
$$\overline{Z}_D/Z_B = 5 \times 10^2 = 500 \text{ longer!}$$

Use

- space gate
- polarization gate
- absorbtion gate

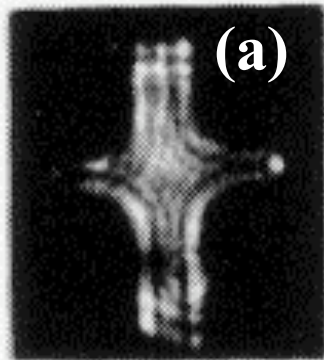
Improves information transfer

Optical Imaging Using Absorption Gating

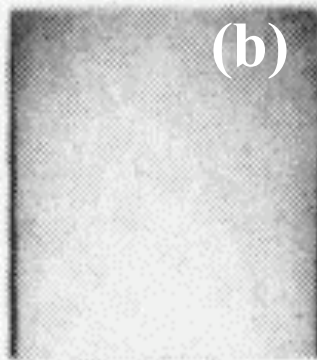


Scattering medium:
10 mm 0.3% latex
beads of $0.29\ \mu\text{m}$
in water

Imaging Setup

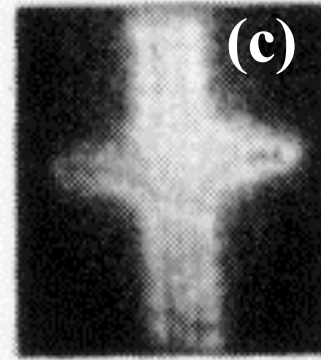


Water



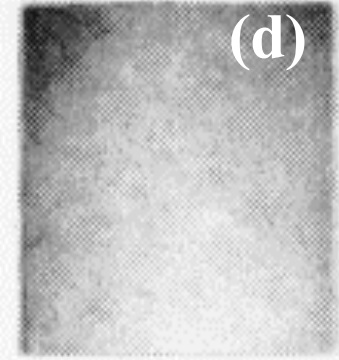
Scattering
only

Red
Light



Scattering &
Absorption
in Red

Red
Light



Scattering &
Absorption
in Red

Green
Light

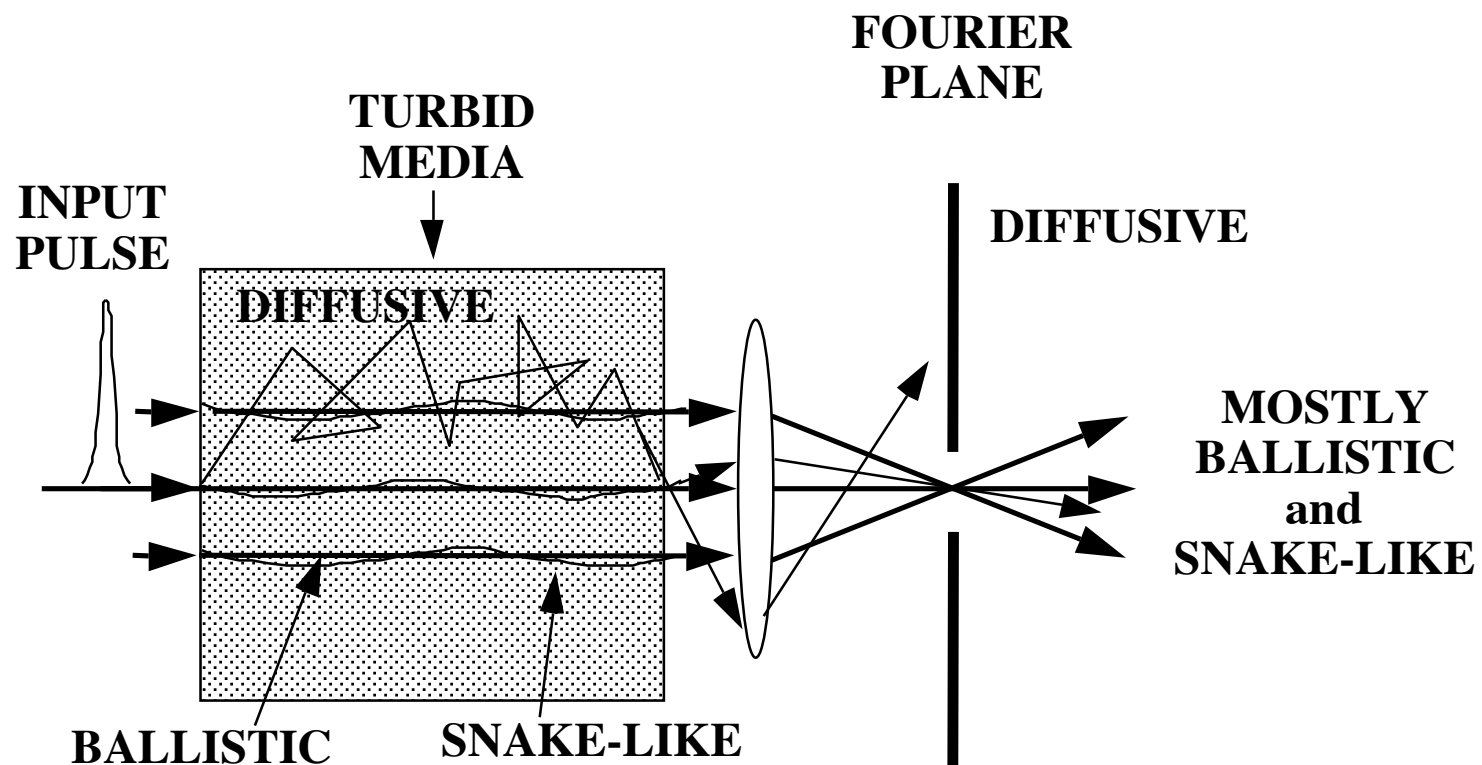
Temporal profile of transmitted pulse through a scattering slab with different absorption

Intensity

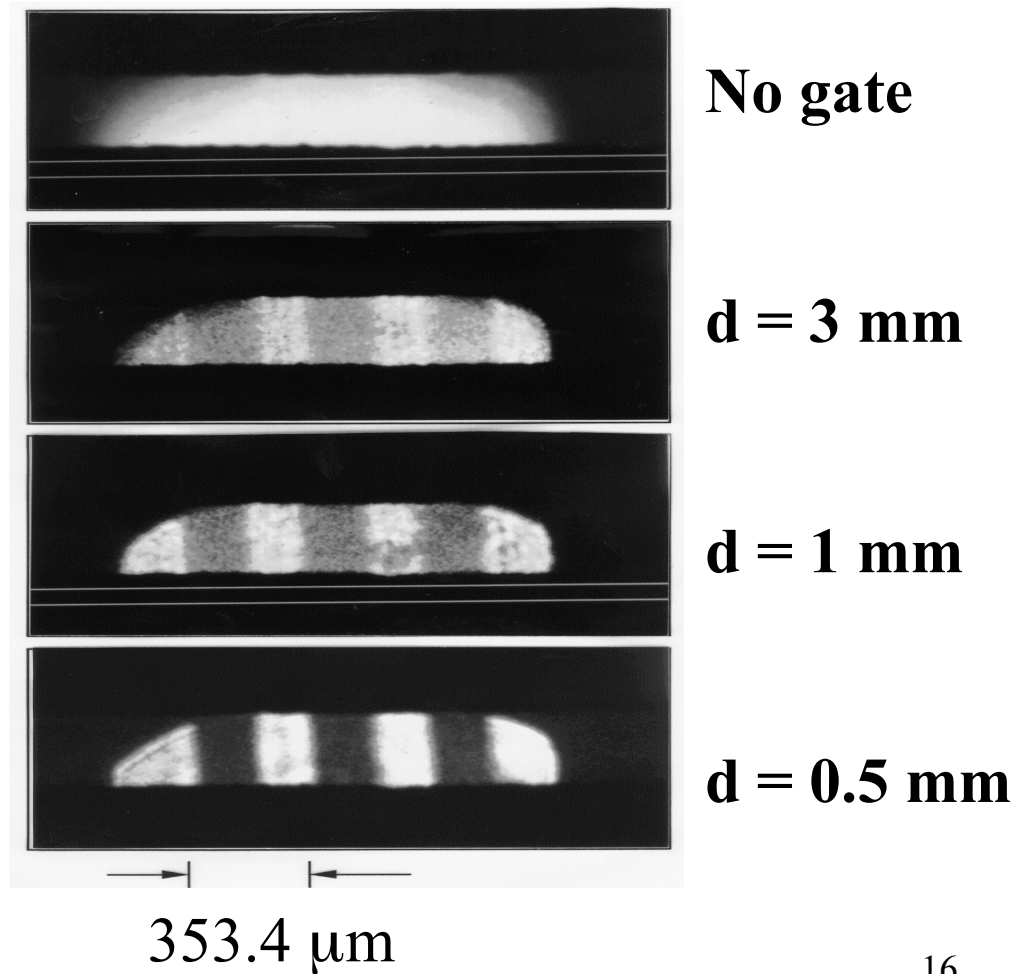
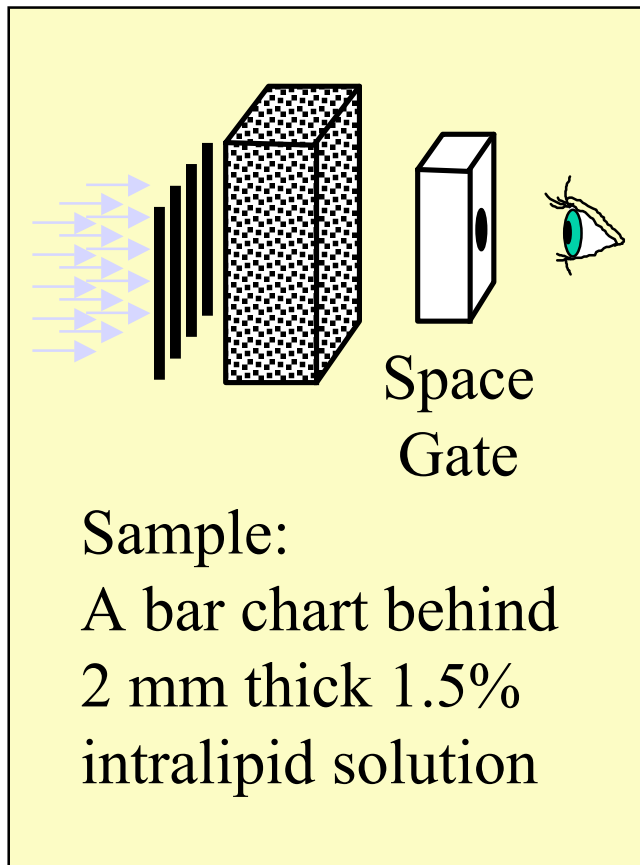
Latex beads
0.33 μm diameter
 $Z = 10$ mm thick
 $Z/l_t = 10$

Time (ps)

Space gate: Optical spatial filters act as time-gating

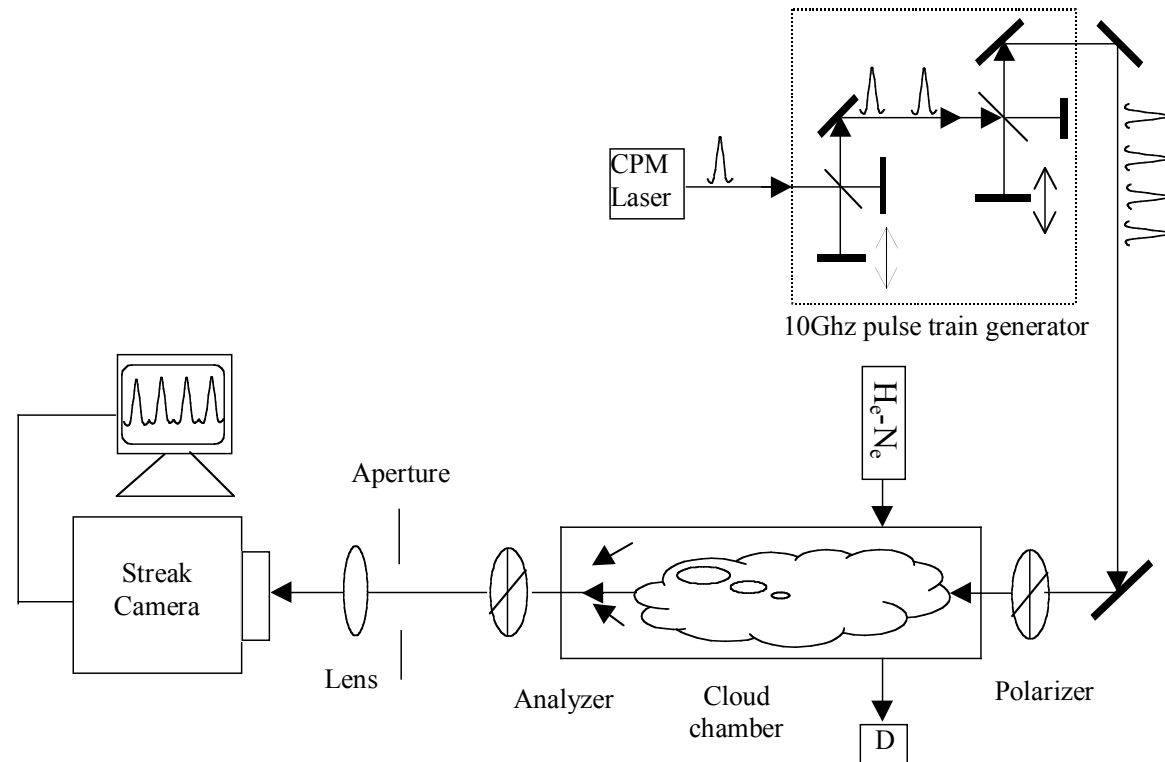


Fourier Space Gating Optical Imaging



Free Space Optical Communication (FSOC) - 1

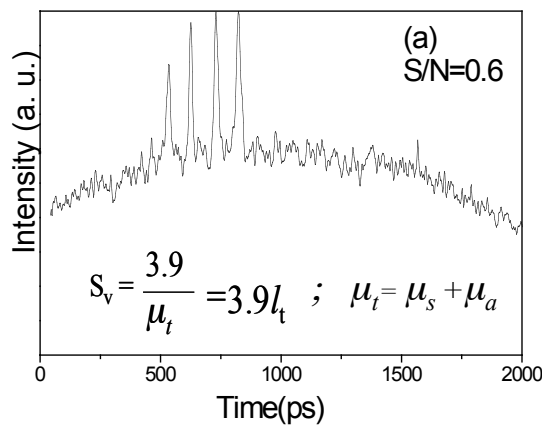
Earth, space - earth



Free Space Optical Communication (FSOC) - 2

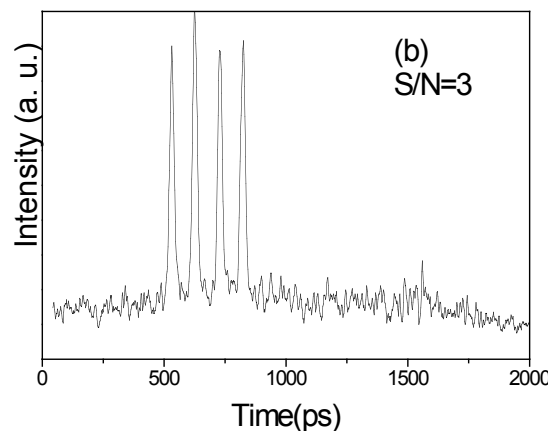
10Gbit/s Wireless Optical Communication in Cloudy Media - Results

$$S_v = 23.7 \text{ cm}$$



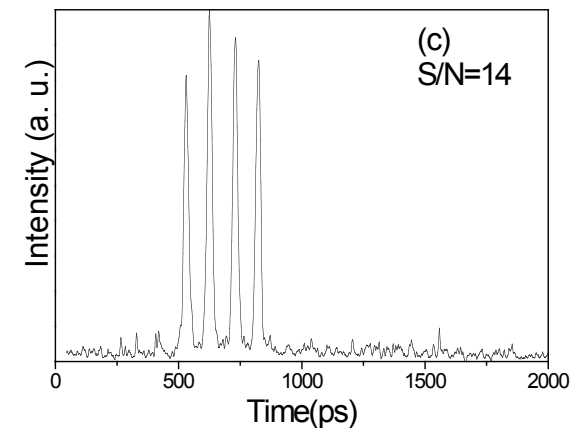
(a) Temporal profiles of the pulse train with a wider streak camera slit (120 channels).

Without polarizer



(b) Temporal profiles of the pulse train with a wider streak camera slit (120 channels).

With polarizer



(c) Temporal profiles of the polarized pulse train with a space gate using narrower streak camera slit (16 chs).

With polarizer and spatial gate

Conclusions

High School, Undergraduate, and Graduate Students can learn state of art lasers and their applications.

New industrial student internships to be implemented (Corning, GE, Lockheed Martin, Philips, Grumman, Ocean Optics)

NASA funding is vital to allow hands-on training